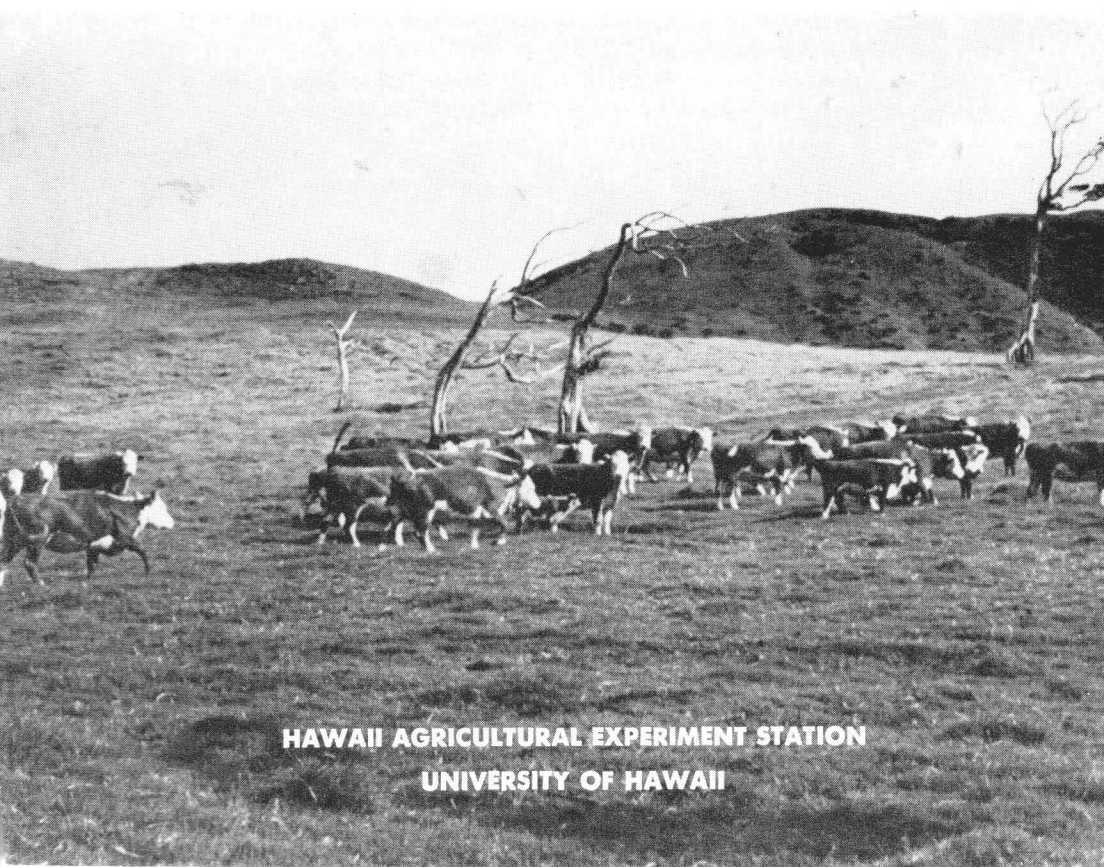


**THE VARIATION IN
PROTEIN AND MINERAL COMPOSITION OF
HAWAII RANGE GRASSES
AND ITS POTENTIAL EFFECT ON CATTLE NUTRITION**

O. R. Younge and K. K. Otagaki



**HAWAII AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF HAWAII**

THE AUTHORS

DR. O. R. YOUNGE is Agronomist at the Hawaii Agricultural Experiment Station and Professor of Agriculture, University of Hawaii.

DR. K. K. OTAGAKI is Assistant Animal Scientist at the Hawaii Agricultural Experiment Station and Assistant Professor of Agriculture, University of Hawaii.

ACKNOWLEDGMENT

Acknowledgment is made to D. W. Edwards, Junior Chemist (resigned), for the chemical analyses; to J. C. Ripperton, Professor Emeritus of Agriculture, for the supervision of the field work; and to Y. Kawano, Junior Chemist, for photographic reproduction of the tabular work.

CONTENTS

	PAGE
INTRODUCTION	5
LITERATURE REVIEW	6
PROCEDURE	6
EXPERIMENTAL RESULTS	6
DISCUSSION	7
Protein and Total Digestible Nutrients	7
Phosphorus	10
Calcium	11
INTRODUCED GRASSES	11
SUMMARY	12
LITERATURE CITED	13
APPENDIX	15
Table 1. Minimal chemical composition of grasses harvested at bimonthly intervals at various locations and soils, island of Hawaii	15
Table 2. Minimum nutrient requirements of beef cattle based upon oven-dry feed	16
Figure 1. Vegetation zones and sampling sites, island of Hawaii	17
Figures 2-11. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors	18



Relatively unimproved range area — rough-cleared native hilograss and ricegrass range in the wet D_1 vegetation zone, elevation 800 feet.

In contrast, see cover photo showing well-kept improved kikuyugrass range in the wet D_2 vegetation zone, elevation 3,000 feet.

THE VARIATION IN PROTEIN AND MINERAL COMPOSITION OF HAWAII RANGE GRASSES AND ITS POTENTIAL EFFECT ON CATTLE NUTRITION

O. R. Young and K. K. Otagaki

INTRODUCTION

It has been known for a long time that certain of the range areas of Hawaii produce forage low in mineral nutrients and protein (8, 28). Little is known, however, regarding the geographical distribution of the suspected deficiencies, the soil families involved, and the duration of shortage. In the investigation reported here, an attempt has been made to encompass wide differences in rainfall, elevation, and soils in order to explore the effect of such variations on forage composition. The field and laboratory investigations were performed during 1931 and 1932. The data cover composition of grasses from ten locations on Hawaii, ranging from the soils associated with the low and dry, desert-like B vegetation zone site at Keamoku on Parker Ranch, through the soils in the C₁, C₂, D₁, and D₂ zones to the high elevation sites in the D₃ zone above Kona and at Ohaikea on Kapapala Ranch as shown in figure 1.

The surface of Hawaii has been classified into vegetation zones on the basis of similarities in floristic composition of the vegetative cover (26). Chief factors controlling plant distribution are climate, elevation, and soil. At lower elevations the tropical and subtropical plants are distributed while at higher elevations plants of the subarctic and temperate regions find adaptation.

Approximate limits of elevation and rainfall for the vegetation zones are as follows:

A zone, 20 inches or less rain, elevation less than 1,000 feet.

B zone, 20 to 40 inches rain, elevation less than 3,000 feet.

C zone, 40 to 60 inches rain, C₁ less than 2,500 feet, C₂ from 2,500 to 4,000 feet.

D zone, 60 inches or more rain, D₁ less than 1,500 feet, D₂ usually 1,500 to 5,000 feet, and D₃ at 4,000 to 7,000 feet.

E zone, 50 inches or less, lies above the D zones, usually above 7,000 feet.

The soil or surface deposits of the land areas of Hawaii have been surveyed and classified into some 400 soil type groupings based on physical and chemical characteristics of the soil material. Soils differ in character because of differences in parent material, topography, climate, vegetative cover, and the duration, intensity, and mode of interaction of the various forces causing soil development. Reference is hereby made to Cline *et al.* (6) for the detailed description and occurrence of Hawaii soils.

A good correlation exists between the major soil groupings and the vegetation zones. In general, the wet D vegetation zones occur on leached

soils and under a high rainfall incidence. Likewise, the droughty A and B vegetation zones occur on soils showing little or no effects of leaching due to low rainfall.

LITERATURE REVIEW

Investigations on nutritionally deficient range and pasture grasses (1, 3, 7, 11, 23) have indicated that the most widespread nutritional deficiencies in forage appear to be protein, phosphorus, calcium, magnesium, iron, copper, and cobalt.

In general, the chemical composition of grasses (2, 8, 9, 12, 14, 17, 19, 23, 24) has shown that in the early vegetative stage, the dry matter content is very low and the protein is relatively high, frequently exceeding 25 percent of dry matter. As the grasses mature, the carbohydrate content increases rapidly whereas the protein content drops sharply and the minerals decline gradually. With approaching maturity, there is a continuing increase in crude fiber and lignin and a pronounced reduction in palatability and digestibility beyond the heading stage. The variation in carotene content of the grasses follows the trend in protein (2, 9, 24). In addition to the variability due to stage of growth, wide differences in composition of grasses also occur with species, available moisture, season, location, and other edaphic and climatic factors (8, 14, 19, 24). The literature of the nutritional value of grasses for cattle has shown that digestibility also varies with species, stage of growth, season, and other physical factors (5, 10, 14, 17, 21, 27, 30). The Committees on Animal Nutrition, National Research Council (4, 20), have brought together the findings of numerous studies in beef and dairy cattle nutrition and have prepared standards of nutrient requirements for different classes of cattle.

PROCEDURE

Ten representative experimental sites were selected on Hawaii at the various test sites shown in figure 1. At each of the locations, plots were laid out on established stands of the predominating grass species after cutting and removing all top growth. Each site consisted of two plots, 25 × 25 feet each, of which one remained an untreated check while the other plot received a top dressing of hydrated lime at the rate of 2,000 pounds per acre and 500 pounds per acre of superphosphate, 20 percent P_2O_5 , applied broadcast. The test sites were fenced to exclude livestock. At approximately two-month intervals over a period of a little more than one year, the plots were harvested and samples removed for chemical analysis. No yield or meteorological records were taken. The fresh samples were oven-dried at the nearest assembly point and forwarded to the laboratory for final analysis. The vegetative materials were analyzed for crude protein ($N \times 6.25$), crude fiber, phosphorus, and calcium, using standard methods of analysis.

EXPERIMENTAL RESULTS

A description of the test sites and some related chemical analyses are presented in table 1. The data for crude protein, phosphorus, and calcium content of the grass species for various sites have been correlated with season on a calendar basis for simplicity and ease of interpretation (see figs. 2 to 11).

A comparison of the analyses of Hawaii range grasses with published data on domesticated grasses produced in mainland and foreign areas shows that the local grasses are relatively low in protein, calcium, and phosphorus, and suggests that they may be unsatisfactory for the adequate nutrition of cattle during part of the year.

The overlap in time resulting from carrying the field experiments beyond the full year usually has resulted in overlapping performance curves when data were plotted on the monthly calendar basis. The overlap or break in the curves usually occurs in the July to September period as shown for the various figures. The break in the curves indicates the start and completion of the field experiments.

DISCUSSION

Protein and Total Digestible Nutrients

A comparison of the figures 2 to 11 makes it evident that crude protein content is highly variable depending on species, location, and environmental factors. Likewise, there is a marked seasonal variation in protein content which appears to be inversely related to daylength, or factors associated with daylength. This lowering of protein content in summer (April to August) cannot be attributed solely to limitation of rainfall, as is usually done, inasmuch as there is a similar trend for the vegetation from the D₁ and D₂ zones where rainfall is excessive rather than deficient, as shown in figures 7, 8, and 9. Where drought occurs, of course, the grasses undergo early maturation and hence a reduction in protein content. However, the drop in protein content shown for the test forages in the wet D zone areas is probably associated with a fluctuating low level of available nitrogen, the deficiency of which becomes more intense as growth and yield tend to increase with increase in daylength (31).

The nutritional requirements of domestic animals have been intensively studied for a considerable period by many investigators, and in 1942 the Committee on Animal Nutrition of the National Research Council undertook to set forth the dietary requirements for different classes and ages of farm animals. The feeding standards in table 2 on the dietary needs of cattle were adapted and modified from a recent report to the Research Council by the committee headed by Burroughs (4). It will be noted that the allowances shown are considered to be minimum for normal growth, health, and production and that more liberal rations would cause no adverse effects. However, as noted by Guilbert and his co-workers (13), "Efficient beef production depends on securing, per acre, the highest returns compatible with maximum production per animal unit and with a quality product. High-percentage calf crops, heavy weaning weights, continuous and rapid growth of young stock, and optimum utilization of feed-lot rations in the fattening process are important to efficiency; and all are based largely upon adequate nutrition. Economical production depends upon the degree of approach to the ideal of optimum that may be practicable under specific conditions."

The fattening of one- to two-year-old beef cattle requires rations containing 8.0 to 18.0 and 1.1 to 2.2 pounds of total digestible nutrients (TDN) and digestible crude protein (DCP), respectively, and requires feed with

a total digestible nutrient value of 69 to 76 percent, as shown in table 2. Work (30) has shown that, in general, the total digestible nutrients of the common, full-grown Hawaii grasses is about 55 percent. On the basis of these data it is likely that the nutrient intake from the type of grasses here discussed will fall short of adequate levels. This means, then, that fattening young cattle on such range grasses alone will not attain the suggested daily gains of 2.2 to 3.0 pounds shown for the standards in table 2. Such daily weight gains will necessitate the range grasses to be enriched by legumes or other high quality supplements.

Supplemental concentrate feeding is kept at a minimum under Hawaii and most other range conditions for management and economic reasons. As a rule, the varying grass diet will only occasionally and incidentally meet the exact dietary requirements of any given class of livestock. In the study reported here, the chemical composition of the various grasses was found to be relatively low compared to domesticated forages in general and thus appears to be unsuited for the higher quality demands of fattening cattle. The major corrective measure, therefore, appears to be the establishment of forage stands which more nearly approach the requirements of grazing cattle. By comparing the feeding standards shown in table 2 with their respective counterparts in the forage for each test site, the limiting nutrients and duration of potential deficiencies during the various seasons may be approximated.

Inspection of the various site data indicates that the protein may be one of the limiting factors at most locations for extended periods of each year for nearly all classes of stock. Only the soils of the Honokaa and Puu Oo series at Ahuolua and Ohaikea, respectively, with their paspalum and quite unpalatable hilograss forages are adequate in total protein for growing young stock in the 800- to 1000-pound categories. This means that on the calculated basis all other classes of stock fail to acquire their protein needs, especially during the summer. The short-season natal redtop grown under dry conditions on Puu Pa soils is markedly deficient in protein at all times and is conspicuously an inferior forage. Despite its poor feed quality, natal redtop is probably a valuable forage in areas where climatic conditions exclude the growth of more nutritious forages, on the theory that a poor grass is better than none at all. Growing cattle continue to gain weight on forages low in protein but the daily gain is much reduced, being of the order of 1 pound or less per head per day when the protein content falls below 5 percent (27). However, for normal growth and weight gains less than 9 percent, total protein in the dry matter of range forage is deficient for all classes of cattle as indicated in table 2.

It may be conjectured, of course, that an animal on nutrient-deficient forage will consume extra large volumes of the feed and thus acquire additional nutrients. It has been shown, however, that for cattle the maximum limit of voluntary consumption on the average is 2.5 pounds of dry matter per 100 pounds weight of the animals. When feed is highly palatable, the volume of consumption may reach as much as 3 pounds dry matter per 100 pounds liveweight (13). Pleasing palatability of the forage is exceedingly

important in inducing the animal to eat to capacity. Usually animals will try to satisfy their full requirement for total digestible nutrients. However, there is little evidence to indicate that animals will consume extra feed beyond the requirement for TDN merely to satisfy the need for other essential nutrients. Conversely, it is common knowledge that where forage is inferior in palatability, the cattle will refuse to eat enough to satisfy even their minimum TDN requirements, as for example where cattle are grazed on hilograss, ricegrass, and yellow foxtailgrass¹, even though these grasses may be entirely satisfactory in their chemical analyses for the various nutrients.

Little has been said about the use of feed protein supplements to correct the widespread deficiencies revealed by the chemical analyses of range grasses in these experiments. Obviously, protein supplements could be provided range cattle but the establishment of such practice is still a long way from reality. It is true that protein supplements are fed in great quantities to dairy animals for the production of milk, but this is economically justified only by the attractive prices obtained for the milk when used for human consumption. One of the most popular protein feed supplements as a rule is cottonseed oil meal, which currently wholesales in Hawaii at about \$100.00 per ton for 41 percent protein material or about \$0.12 per pound of protein. A 500-pound beef animal fed liberally for growth requires about 1 pound of digestible protein per day, which in terms of 80 percent digestible protein in cottonseed oil meal is valued at \$0.15. It is obvious that if the growing animal gains at the satisfactory rate of about 1.5 pounds per day, which at the present market value of \$0.25 per pound is worth slightly over \$0.37, then nearly half of the value of weight gain would go to pay for the needed protein if this were to be purchased as a feed supplement.

Alternatively, urea may be used as a substitute for protein up to about 25 percent of the total protein requirement for cattle (22, 25). Commercial urea, 42 percent nitrogen, costs about \$200.00 per ton. Assuming 70 percent efficiency in the conversion of the urea nitrogen to digestible protein, this is equivalent to about \$0.054 per pound of digestible protein or about one-third of the cost of the cottonseed meal protein. It must be remembered, however, that urea furnishes no energy to the animal, whereas cottonseed oil meal furnishes both protein and energy. Urea must be mixed thoroughly with other feeds to prevent beef cattle from consuming a toxic amount. Ranchers have found a proper mixture of urea and molasses to be satisfactory for range supplementation.

The traditional way to improve the dietary level of protein in beef cattle forage is through the production of high quality grasses and the addition of legumes to the sward. As already stated above, this appears possible of attainment only in areas where yield increases will bear the cost of liming and fertilization. In areas where treatment will not increase forage yields in step with increased costs, another alternative is to find or establish small

¹Ricegrass is *Paspalum obiculare*; yellow foxtailgrass is *Setaria geniculata*. Grasses not otherwise identified are listed in table 1.

select areas within larger unfavorable range areas and to intensively improve these for the production of supplementary high protein grazing or soilage crops. Of course, one could make little or no attempt at improvement and be content with the returns from producing inferior beef from slowly growing beef cattle. Naturally, this alternative should not be accepted until positive solutions have been proven ineffective.

Where readily available carbohydrates are deficient in the feed for cattle, it is, of course, possible to supplement the ration with feed concentrates such as molasses and various grains (15, 16, 29).

Phosphorus

As shown by the chemical data and the nutrient standards, there is definite evidence of forage phosphorus deficiencies in many areas of Hawaii, the supplies usually being at their lowest during summer months. The phosphorus levels are deficient for young growing cattle and for beef cows with calves on all ten test soils except the Waimea. Moderate to severe phosphorus deficiencies are shown to exist on the Puu Pa, Waikalooa, Kapapala, Honokaa, and Puu Oo soils, with varying periods with phosphorus content below 0.20 percent. Acute phosphorus deficiencies occur in forage on the Olaa and Akaka soils, where over extended periods the phosphorus content falls below the critical value of 0.17 percent. The addition of 500 pounds of superphosphate and one ton of liming material per acre produced a slight improvement in the phosphorus content of the forage, but in most cases the increased content failed to alleviate the deficiencies. Based on the phosphorus requirement for beef cows, the forage on the Puu Pa, Olaa, and Akaka soils is deficient for varying periods even for maintenance of mature cows, which require a ration with a minimum of 0.20 percent phosphorus.

It should be noted and emphasized that mineral deficiencies are generally avoided when the daily forage ration contains as little as two pounds of dry matter from legumes of good quality. Thus, if the range provides on the order of 15 to 25 percent of the grazeable forage as legumes, there is little likelihood of phosphorus or calcium deficiencies for any class of cattle. The critical factor of this situation is that on most Hawaii soils, and especially in the severely leached wetland areas, the untreated soils are too low in calcium and other minerals to allow legumes to flourish and hence the forage contains few or no legumes. In practice the mineral deficiency situation undoubtedly has to be approached from two angles; one is by correcting deficiencies through the feeding of supplements, the other is by liming and fertilizing the land where justified by increased yields so that high quality grasses and legumes may flourish and thus render supplementation unnecessary. The feeding of supplements is ordinarily the first practice to be undertaken. On the basis of the chemical data presented, it is evident that supplements of phosphorus are required on all soils except possibly the Waimea and Honokaa soil families. The Puu Pa, Waikalooa, Kapapala, Olaa, Akaka, and Puu Oo soils all produce grasses deficient in phosphorus. The addition of one ton of limestone and 500 pounds of superphosphate per acre, while providing some improvement failed to raise the phosphorus level to adequate levels during the one-year period following treatment.

This would indicate that insufficient amounts were added or that possibly the minerals were rendered unavailable to plants due to lack of water or because of rapid fixation in the soil.

Visual symptoms of phosphorus deficiency in Hawaii cattle are practically unknown probably because the deficiency usually is complicated and masked by more acute deficiencies, such as in protein or total nutrient intake, which slow down growth and reduce the phosphorus requirement accordingly.

Calcium

Calcium is an element needed by cattle for formation of bone and is an essential element of meat and blood. Lack of adequate requirements is not usually reflected in visual symptoms and the occurrence of severe calcium deficiency in beef cattle is comparatively rare. Severe privation may so deplete the bones of calcium that they become brittle and fractures may occur. The addition of calcium to deficient rations stimulates the appetite, increases the rate of gain, improves feed utilization, results in heavier bone development, and improves the quality of beef produced (1, 7, 10, 13, 17, 20). The experimental forage data indicate that fattening young cattle in the 400-pound class require additional calcium at certain seasons at all ten locations other than on the Honokaa and Puu Oo soils, the minimum calcium requirement being 0.41 percent. Once the cattle reach the 600-pound weight their calcium needs are met on most test soils other than the Olaa and Akaka soils, although the margin over the requirement is quite narrow at certain seasons and locations. The addition of nominal amounts of liming materials of the order of one to two tons per acre apparently would shift the calcium-deficient forages above the critical level for most classes of beef cattle. It will be noted, however, that the forages grown on all test soils fall well below the 0.8 percent calcium level considered normal for satisfactory forage according to Orr (23), and in several cases fall below the critical limit of 0.35 percent for growing animals according to Becker (1). The absence of visual calcium deficiency symptoms in Hawaii cattle is probably masked by the more acute protein deficiency, which in turn slows growth of the cattle to levels where the available calcium is adequate or it may be due to the scarcity of cattle in calcium-deficient areas because of forest cover or other factors.

Supposing that all calcium needed by a 500- to 1000-pound animal, estimated at 20 grams per day (0.7 ounces), is to be supplied by powdered limestone, the quantity of pure CaCO_3 needed would be provided by 59 grams or roughly 2 ounces of material per day for most classes of stock. Inasmuch as powdered lime costs only a few cents per pound, there is actually little reason for cattle rations being deficient in calcium when it can be incorporated readily with molasses and other supplemental feeds.

INTRODUCED GRASSES

In addition to the experiments on native forage composition reported in this paper, published data are available for the Keamoku and Waikii sites on various small plot plantings of introduced species not currently forming

the native sward (8). Table 1 and figure 2 show the composition of kikuyu and rhodesgrass in addition to the established natal redtop at Keamoku. At Waikii, introduced kikuyu and paspalum are reported in addition to established bermudagrass (fig. 3). The data indicate that there are marked differences in chemical composition associated with species. In all cases the introductions are equal or superior to the native grasses. Some of this superiority in composition may be due to the fact that the introductions were grown on renovated land and kept free of competition from weeds. At Keamoku, the kikuyu and rhodesgrass produced considerably longer grazing than the natal redtop, and the protein and calcium contents were obviously satisfactory for growing young cattle and breeding stock. The phosphorus level, however, was deficient for all three grass species.

At the Waikii location, the protein contents of kikuyu, paspalum, and bermudagrass were all deficient in the May-September period. The calcium content was satisfactory and considerably higher for the two recent introductions than for the range bermudagrass. The phosphorus content of kikuyu was satisfactory and about twice as high as that of the paspalum and bermudagrass, both of which approached deficiency levels during the summer season for certain classes of stock.

The results for the several species at two locations clearly indicate that species characteristics influence composition as well as do soil and climatic environment. Likewise, it is apparent that it is the favorable combination of all growth factors that makes for good quality forage. In general it can be said that it is the factors which are unfavorable or in critical supply which exert the chief control in growth performance. A grass species with low capacity for mineral elaboration will obviously produce forage low in elements such as calcium or phosphorus. Similarly, a soil low in available chemical elements is likely to produce forage limited in these constituents. When both the soil environment and plant species are inferior in their capabilities, it is certain the resulting yield will be of low quality. The variation in composition of the several species for the same soil areas appears to agree with this concept. The conclusion is that as far as economic feasibility permits, effort should be made to ameliorate or reduce the controlling or critical factors holding back the production of high quality forage, whether this factor be low fertility, inferior species, or management.

SUMMARY

Native or naturally established grasses from ten different locations and soils on the island of Hawaii were sampled at two-month intervals over a period of a little over one year and their chemical composition determined. Data are presented on the seasonal trend of crude protein, phosphorus, and calcium, and compared with the nutrient requirements established for different classes of cattle by the Committees on Animal Nutrition, National Research Council, U.S.A.

The crude protein is shown to be deficient in amount for all classes of cattle during the five-month period April to August. The reduction in protein during the summer period occurs in wet and dry areas alike and is probably induced by the limited availability of soil nitrogen in the wet areas

and the hastened maturity of the grasses in droughty areas. Only the Honokaa and Puu Oo soils at the Ahualoa and Ohaikea sites, with hilograss and paspalum, respectively, meet the minimum protein standards for maturing young stock in the 800- to 1000-pound class, the class with the lowest maintenance requirements next to mature cows. For other classes of cattle, the protein content is considerably below minimum standards most of the time for growing young cattle below 600 pounds and for fattening cattle at all weights and ages.

The phosphorus and calcium content of the native grasses follow the trend of protein, being low during several months during the long-day and summer period. Calcium is prevailing below the desirable 0.8 percent level for all grasses on all soils. It falls below the minimum standards for young cattle in the 400- and 500-pound categories for various grasses on all soils except the Honokaa and Puu Oo soils. The periods of deficiency range from one month to all year round and appear to occur with the greatest frequency in the B and C vegetation zones. However, only the carpet-grass on Olaa soils fell below the critical level for all classes of cattle, the period of deficiency lasting from November through February. The unsatisfactory mineral content of the forage on this soil is associated furthermore with a low protein content. Top dressing with one ton of liming material per acre raised the calcium content of the forage in general but at sites of severest deficiency failed to produce satisfactory levels of calcium for all classes of cattle.

In most grasses phosphorus deficiencies existed seasonally during the long-day period, May to September, for young growing and fattening cattle. The minimal level for all cattle, 0.17 percent, occurred for varying periods ranging up to several months for grasses grown at six locations scattered over all vegetation zones. Surface treatment with 500 pounds per acre of superphosphate slightly increased the phosphorus content of the forage but usually the increase failed to correct the nutritional deficiency. Suggestions are presented for the alleviation of the nutritional deficiencies found in the range grasses.

On the basis of the chemical content of the native grasses from ten widely different soils ranging from the dry Reddish Brown soil group through the Reddish Prairie, Brown Forest, and extremely wet Hydrol Humic Lato-sols, it is apparent that serious widespread nutritional deficiencies exist for various classes of beef cattle. Prevailing the grasses fail to meet minimum standards of protein and phosphorus, and for extended periods calcium is apparently also deficient.

LITERATURE CITED

- (1) BECKER, R. B., ET AL. 1933. EFFECTS OF CALCIUM-DEFICIENT ROUGHAGE UPON MILK PRODUCTION AND WELFARE OF DAIRY COWS. Florida Agr. Expt. Sta. Tech. Bul. 262, 27 pp.
- (2) BIRD, J. N. 1943. STAGE OF CUTTING STUDIES: GRASSES. J. Agron. 35: 845-861.
- (3) BLACK, W. H., ET AL. 1949. COMPARISON OF METHODS OF SUPPLYING PHOSPHORUS TO RANGE CATTLE. USDA Tech. Bul. 98, 22 pp.
- (4) BURROUGHS, W., ET AL. 1958. NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS IV. NUTRIENT REQUIREMENTS OF BEEF CATTLE. Publication 579, National Res. Council., Washington, D. C. 32 pp.

- (5) CAMPBELL, R. S., ET AL. 1954. NUTRITIVE VALUES OF NATIVE PLANTS ON FOREST RANGE IN CENTRAL LOUISIANA. Louisiana Agr. Expt. Sta. Bul. 488, 18 pp.
- (6) CLINE, M. G., ET AL. 1955. SOIL SURVEY OF THE TERRITORY OF HAWAII. USDA Soil Survey Ser. 1939, No. 25.
- (7) DAVIDSON, W. B. 1945. NUTRITIONAL DEFICIENCY DISEASES, THEIR SOURCES AND EFFECTS. Canada J. Compar. Med. 9: 155-162.
- (8) EDWARDS, D. W., and R. A. GOFF. 1935. FACTORS AFFECTING THE CHEMICAL COMPOSITION OF PASTURE GRASSES. Hawaii Agr. Expt. Sta. Bul. 76, 31 pp.
- (9) FRAPS, G. S., and J. F. FUDGE. 1945. CHEMICAL COMPOSITION OF SIXTY-FOUR SPECIES OF RANGE PASTURE GRASS GROWN ON A VICTORIA CLAY LOAM. J. Agron. 37: 251-258.
- (10) FRIEDMAN, M. H., and W. A. TURNER. 1939. NUTRITION AND REPRODUCTION. USDA Yearbook: 482-491.
- (11) GRAHAM, MARQUIS OF, and T. D. HALL. 1933. PASTURE INVESTIGATIONS IN SOUTHERN RHODESIA, South African Jour. of Sci. 30: 288-306.
- (12) GRAVES, R. R., J. R. DAWSON, V. D. KOPLAND, and T. W. MOSELEY. 1933. FEEDING VALUE FOR MILK PRODUCTION OF PASTURE GRASSES WHEN GRAZED, WHEN FED GREEN AND WHEN FED AS HAY OR SILAGE. USDA Tech. Bul. 381.
- (13) GUILBERT, H. R., ET AL. 1950. RECOMMENDED NUTRIENT ALLOWANCES FOR DOMESTIC ANIMALS. IV. RECOMMENDED NUTRIENT ALLOWANCES FOR BEEF CATTLE. National Res. Council, Washington, D. C., 37 pp.
- (14) HART, C. H., H. R. GUILBERT, and H. GOSS. 1932. SEASONAL CHANGES IN THE CHEMICAL COMPOSITION OF RANGE FORAGE AND THEIR RELATION TO NUTRITION OF ANIMALS. California Agr. Expt. Sta. Bul. 543, 66 pp.
- (15) HENKE, L. A. 1940. CANE MOLASSES FOR PASTURE FATTENING OF BEEF CATTLE. Hawaii Agr. Expt. Sta. Ann. Rpt., pp. 27-29.
- (16) HENKE, L. A., S. H. WORK, and W. A. BURT. 1940. BEEF CATTLE FEEDING IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 85, 37 pp.
- (17) HUFFMAN, C. F. 1939. ROUGHAGE QUALITY AND QUANTITY IN THE DAIRY RATION, A REVIEW. J. Dairy Sci. 22: 889-980.
- (18) JOHNSON, M. O., and K. A. CHING. 1918. COMPOSITION AND DIGESTIBILITY OF FEEDING STUFFS GROWN IN HAWAII. Hawaii Agr. Expt. Sta. Press Bul. 53, 26 pp.
- (19) JOHNSTONE-WALLACE, D. B. 1937. THE INFLUENCE OF GRAZING MANAGEMENT AND PLANT ASSOCIATIONS ON THE CHEMICAL COMPOSITION OF PASTURE PLANTS. J. Agron. 29: 441-455.
- (20) LOOSLI, J. K., ET AL. 1956. NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS. III. NUTRIENT REQUIREMENTS OF DAIRY CATTLE. National Res. Council, Washington, D. C., 30 pp.
- (21) MAYNARD, L. A. 1937. INTERPRETATION OF VARIATIONS IN PLANT COMPOSITION IN RELATION TO FEEDING VALUE. J. Agron. 29: 504-511.
- (22) OTAGAKI, K. K., O. WAYMAN, K. MORITA, and I. I. IWANAGA. 1956. UTILIZATION OF NONPROTEIN NITROGEN IN RATIONS OF MILKING COWS UNDER HAWAII CONDITIONS. J. Dairy Sci. 39: 1753-1758.
- (23) ORR, J. B., and H. SHERBATOFF. 1929. MINERALS IN PASTURES AND THEIR RELATION TO ANIMAL NUTRITION. Lewis and Co., London, England, 150 pp.
- (24) PHILLIPS, T. G., J. T. SULLIVAN, M. E. LOUGHLIN and V. G. SPRAGUE. 1954. CHEMICAL COMPOSITION OF SOME FORAGE GRASSES. I. CHANGES WITH PLANT MATURITY. J. Agron. 46: 361-369.
- (25) REID, J. T. 1953. UREA AS A PROTEIN REPLACEMENT FOR RUMINANTS: A REVIEW. J. Dairy Sci. 36: 955.
- (26) RIPPERTON, J. C., and E. Y. HOSAKA. 1942. VEGETATION ZONES OF HAWAII. Hawaii Agr. Expt. Sta. Bul. 89, 61 pp.
- (27) ROUBICEK, C. T., R. T. CLARK, and O. F. PAHNISH. 1957. RANGE CATTLE PRODUCTION. 6. MATERNAL FACTORS. A LITERATURE REVIEW. Arizona Agr. Expt. Sta. Rpt. 146, 49 pp.
- (28) SHOREY, E. C. 1906. LIME AS AN ESSENTIAL FACTOR IN FORAGE. Hawaii Agr. Expt. Sta. Press Bul. 15, 6 pp.
- (29) WAYMAN, O., and I. I. IWANAGA. 1956. FURTHER STUDIES ON THE USE OF RATIONS HIGH IN MOLASSES FOR FATTENING BEEF CATTLE. Hawaii Agr. Expt. Sta. Progress Notes No. 110, 7 pp.
- (30) WORK, S. H. 1946. DIGESTIBLE NUTRIENT CONTENT OF SOME HAWAIIAN FEEDS AND FORAGES. Hawaii Agr. Expt. Sta. Tech. Bul. 4, 22 pp.
- (31) YOUNGE, O. R., and M. TAKAHASHI. 1953. RESPONSE OF ALFALFA TO MOLYBDENUM IN HAWAII. J. Agron. 45: 420-428.

APPENDIX

TABLE 1. Minimal chemical composition of grasses harvested at bimonthly intervals at various locations and soils, island of Hawaii¹

SITE NO.	GRASSES ²	LOCATION	VEGE- TATION	RAIN- FALL PER YEAR	SOIL		COW- DAYS PER ACRE PER YEAR	MINIMUM CHEMICAL COMPOSITION IN D.M. ⁴						CRUDE FIBER ⁶	
								Protein		P		Ca			
					Group	Soil series		Check	Fertz ⁵	Check	Fertz	Check	Fertz	Min.	Max.
			Zone	Inches				%	%	%	%	%	%	%	%
1	Kikuyu ²	Keamoku, Parker Ranch	B	25	Reddish Brown	Puu Pa	20	7.2	—	.44	—	.70	—	—	—
	Natal redtop							3.4	4.5	.096	.100	.34	.42	27.3	30.7
	Rhodesgrass ³							9.1	—	.07	—	.74	—	—	—
2	Rhodesgrass	Puu Waawaa Ranch	C ₂	25	Reddish Brown	Waikalooa	35	6.4	4.7	.144	.166	.32	.39	28.4	35.9
3	Bermudagrass	Waikii, Parker Ranch	C ₂	25	Reddish Prairie	Waimea	100	7.2	7.8	.262	.280	.34	.36	24.2	24.5
	Kikuyu ²							7.2	—	.44	—	.70	—	—	—
	Paspalum ³							7.8	—	.24	—	.52	—	—	—
4	Bermudagrass	Kahua Ranch	C ₂	25	Reddish Prairie	Waimea	100	6.4	7.1	.218	.244	.29	.34	25.5	27.7
5	Bermudagrass and smooth kukaipuaa	Kapapala Ranch, lower	C ₂	50	Brown Forest (Latosolic)	Kapapala	100	6.0	5.7	.118	.140	.30	.31	24.3	25.5
6	Carpetgrass	Waipahoehoe	D ₁	150	Hydrol Humic Latosol	Olaa	30	6.7	6.1	.074	.114	.17	.28	26.3	27.8
7	Carpetgrass	Volcano, Shipman Ranch	D ₂	150	Hydrol Humic Latosol	Akaka	10	6.5	5.7	.039	.157	.19	.40	22.6	27.0
8	Hiligrass	Ahuoloa, Parker Ranch	D ₂	80	Hydrol Humic Latosol	Honokaa	120	8.9	8.5	.179	.210	.59	.59	25.5	27.7
9	Hiligrass	Kona, mauka	D ₃	60	Brown Forest (Latosolic)	Puu Oo	90	6.0	6.0	.105	.131	.46	.52	28.0	28.9
10	Paspalum	Ohaieka, Kapapala Ranch	D ₃	60	Brown Forest (Latosolic)	Puu Oo	90	8.7	7.0	.175	.118	.43	.58	27.0	—

¹Data on soils and carrying capacity from Cline *et al.* (6); vegetation zones from Ripperton and Hosaka (26).

²Kikuyu=*Pennisetum clandestinum*, natal redtop=*Rhynchelytrum repens*, rhodesgrass=*Chloris gayana*, bermudagrass=*Cynodon dactylon*, paspalum=*Paspalum dilatatum*, kukaipuaa=*Digitaria pruriens*, carpetgrass=*Axonopus affinis*, hiligrass=*Paspalum conjugatum*.

³Data on chemical composition from Edwards and Goff (8).

⁴For minimal nutrient limits for various classes of cattle see table 2.

⁵Fertilizer broadcast 500 pounds superphosphate, 20 percent P₂O₅, and 2000 pounds of hydrated lime per acre.

⁶Crude fiber content shown for the unfertilized forage, fertilization caused no apparent change in fiber content.

TABLE 2. Minimum nutrient requirements of beef cattle based upon oven-dry feed ^{1 2}

BODY WEIGHT	EXPECTED DAILY GAINS ³	DAILY FEED		PERCENTAGE OF RATION OR AMOUNT, PER POUND OF FEED										Carotene ⁸	Vitamin A ⁹
		Percent of live-weight	Per animal	Protein		Total digestible nutrients		Digestible energy ⁵	Calcium ⁶		Phosphorus ⁷				
				60% digestible ⁴	Total digestible										
lb.	lb.	%	lb.	%	lb.	%	lb.	therms/lb.	%	gm.	%	gm.	mg/lb.	IU/lb.	
Normal growth, beef heifers and steers															
400	1.6	2.7	10.8	13.0	0.8	64	7.0	1.29	0.32	16	0.23	11	0.5	308	
600	1.4	2.4	14.4	10.4	0.9	59	8.5	1.18	0.22	15	0.18	12	0.6	308	
800	1.2	2.2	17.1	8.7	0.9	56	9.6	1.11	0.19	15	0.17	13	0.7	369	
1000	1.0	1.9	18.9	8.7	1.0	55	10.4	1.11	0.16	14	0.17	15	0.8	431	
Fattening calves finished as short yearlings															
400	2.3	2.7	10.8	15.2	1.1	74	8.0	1.48	0.41	20	0.31	15	0.6	308	
600	2.4	2.4	14.4	15.2	1.3	76	10.9	1.51	0.31	20	0.26	17	0.6	308	
800	2.2	2.3	18.0	13.9	1.5	76	13.7	1.51	0.24	20	0.22	18	0.7	369	
1000	2.2	2.0	19.8	13.9	1.6	76	15.0	1.51	0.22	20	0.22	20	0.8	431	
Fattening yearling cattle															
600	2.4	2.7	16.2	13.9	1.3	72	11.7	1.44	0.28	21	0.23	17	0.6	308	
800	2.8	2.5	19.8	13.9	1.6	72	14.3	1.44	0.22	20	0.22	20	0.6	308	
1000	2.5	2.3	23.4	13.9	1.9	72	16.8	1.44	0.19	20	0.22	23	0.6	308	
1100	2.3	2.2	24.3	13.9	2.0	72	17.5	1.44	0.18	20	0.22	24	0.7	369	
Fattening two-year cattle															
800	2.8	2.7	21.6	13.9	1.8	69	14.9	1.38	0.20	20	0.22	22	0.6	308	
1000	3.0	2.4	24.3	13.9	2.0	69	16.7	1.38	0.18	20	0.22	24	0.6	308	
1200	2.6	2.2	26.1	13.9	2.2	69	18.0	1.38	0.17	20	0.22	26	0.7	369	
Cows nursing calves, first 3-4 months postpartum															
900 to 1100	0.0	2.5	25.2	9.3	1.5	67	16.9	1.33	0.27	31	0.20	23	4.0	1332	

¹Committee on Animal Nutrition, Subcommittee on Beef Cattle Nutrition. National Research Council (4).

²Table modified from basis of 90 percent dry matter to 100 percent dry matter.

³Average daily gain for fattening cattle is based on cattle receiving stilbestrol under feedlot conditions. Fattening cattle not receiving stilbestrol gain from 10 to 20 percent slower than the indicated values.

⁴Digestibility of crude protein of Hawaii grasses is approximately 60 percent (30).

⁵Digestible energy (DE) was calculated on the assumption that one gram of total digestible nutrients (TDN) contains 4.41 kilocalories (kcal.) of DE. The formula for converting kcal. per gram to therms per pounds is:

$$\text{Therms DE} = \text{lb. TDN} \times 454 \text{ gm.} \times 4.41 \text{ kcal.}$$

$$1000 \text{ kcal.}$$

DE may be converted to metabolizable energy by multiplying by 82 percent.

⁶Calcium in feed calculated to be approximately utilized with 50 percent efficiency (13).

⁷Phosphorus in feed calculated to be approximately utilized with 60 percent efficiency (13).

⁸ β -carotene requirement computed on basis of 1.4 mg. β -carotene/100 pounds body weight.

⁹Vitamin A requirement computed on basis of 1 mg. β -carotene equals 554 IU vitamin A. For reproduction or storage vitamin A requirement computed on basis of 1 mg. β -carotene equals 333 IU vitamin A.

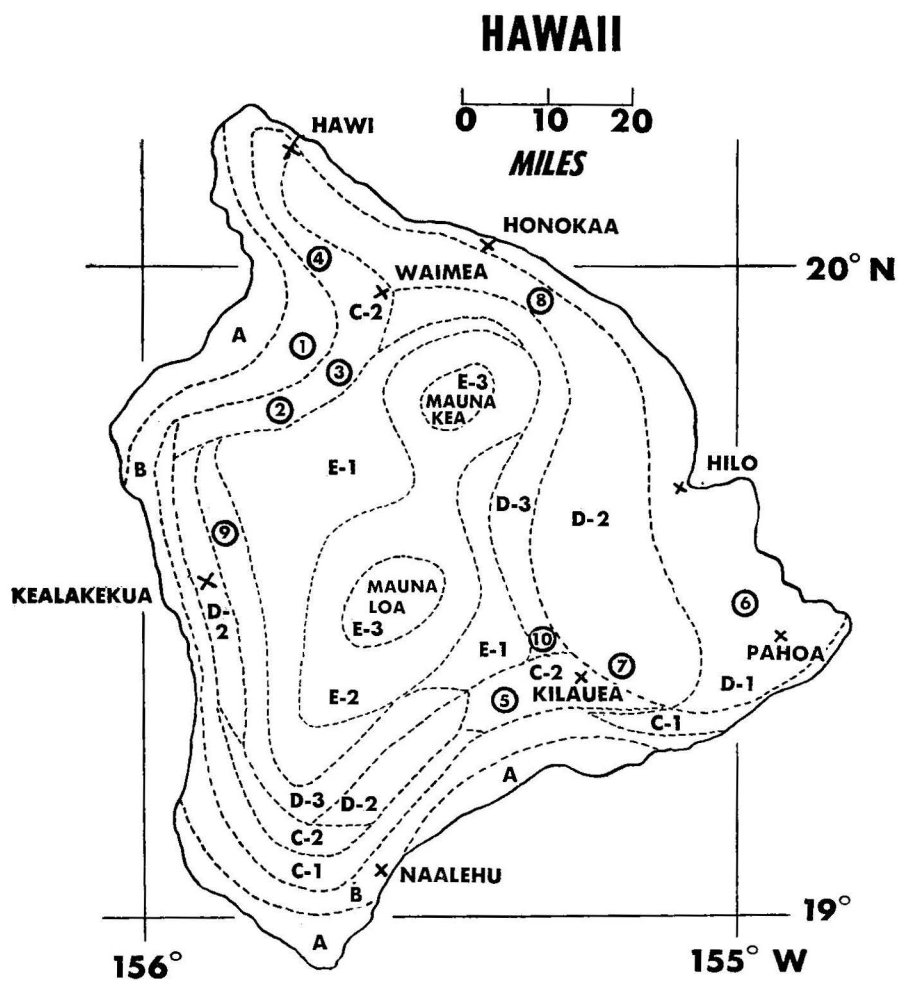


FIGURE 1. Vegetation zones and sampling sites, island of Hawaii (data in table 1).

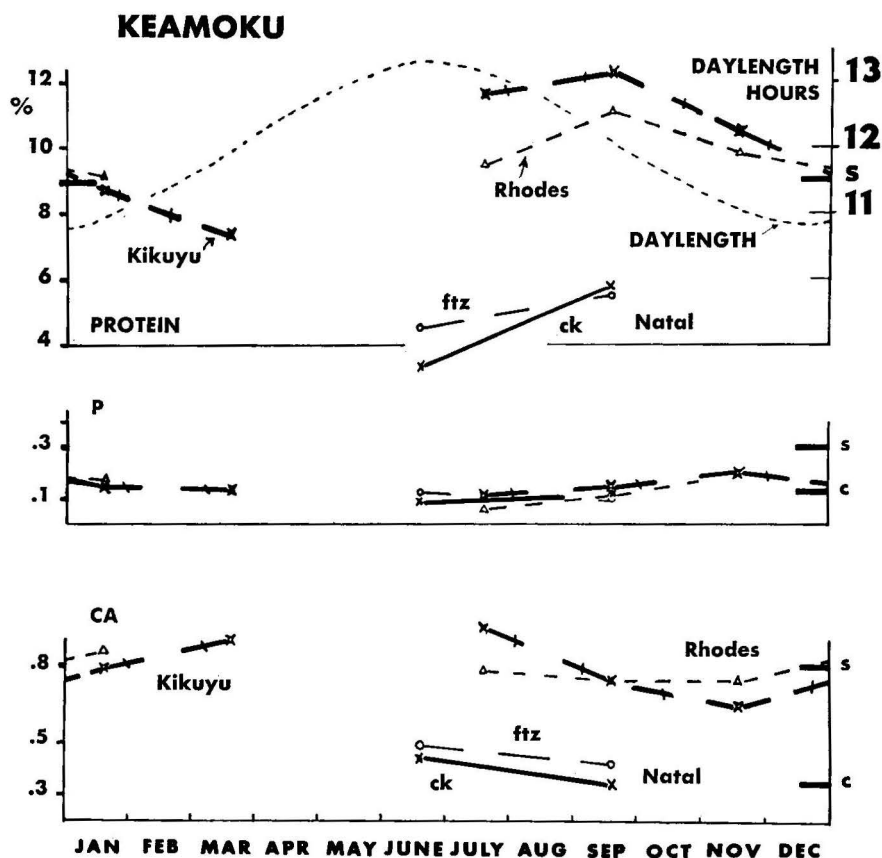


FIGURE 2. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization. Data on kikuyu and rhodesgrass are from Edwards and Goff (8).

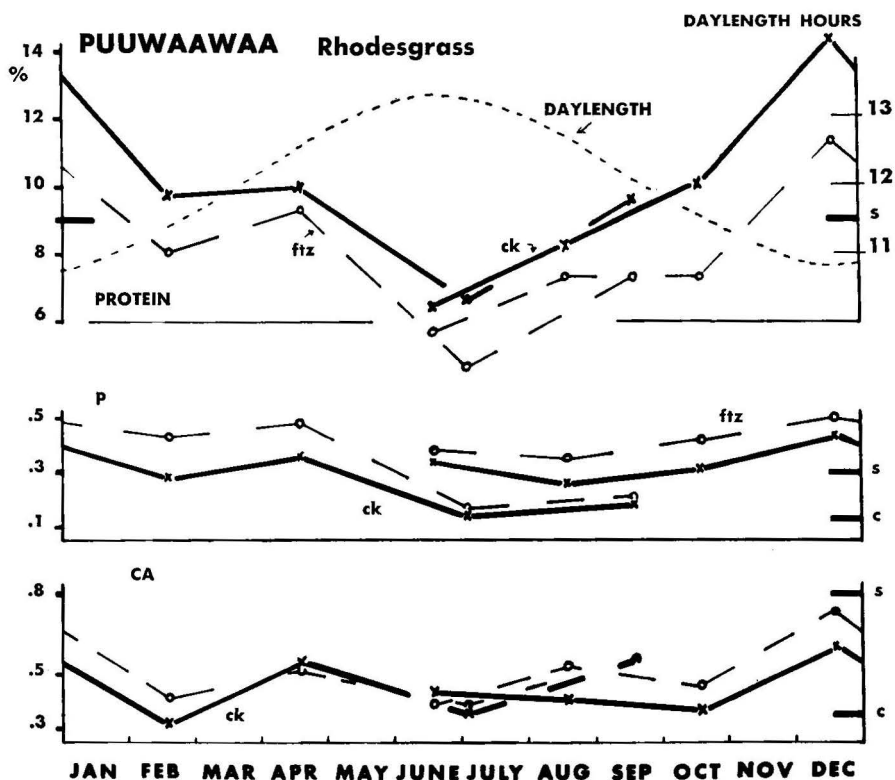


FIGURE 3. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

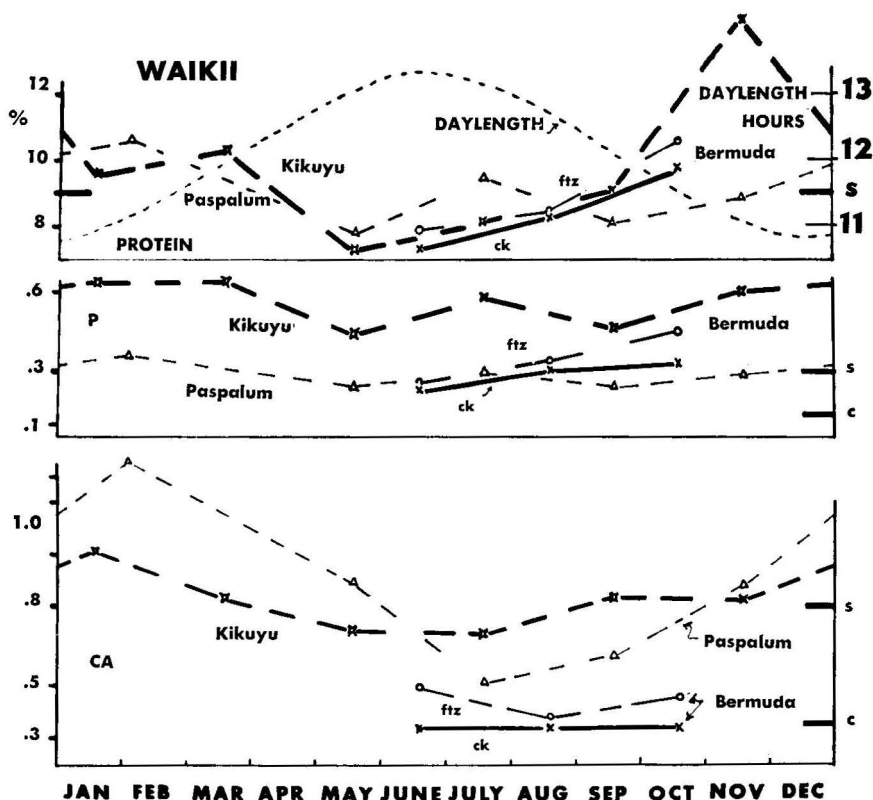


FIGURE 4. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization. Data on kikuyu and paspalum are from Edwards and Goff (8).

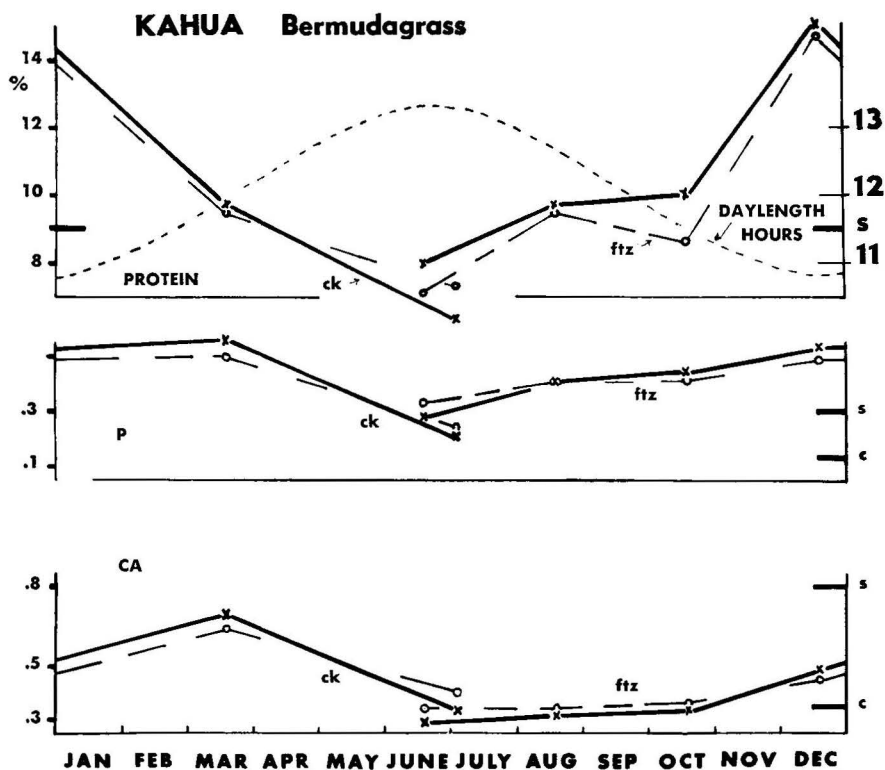


FIGURE 5. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

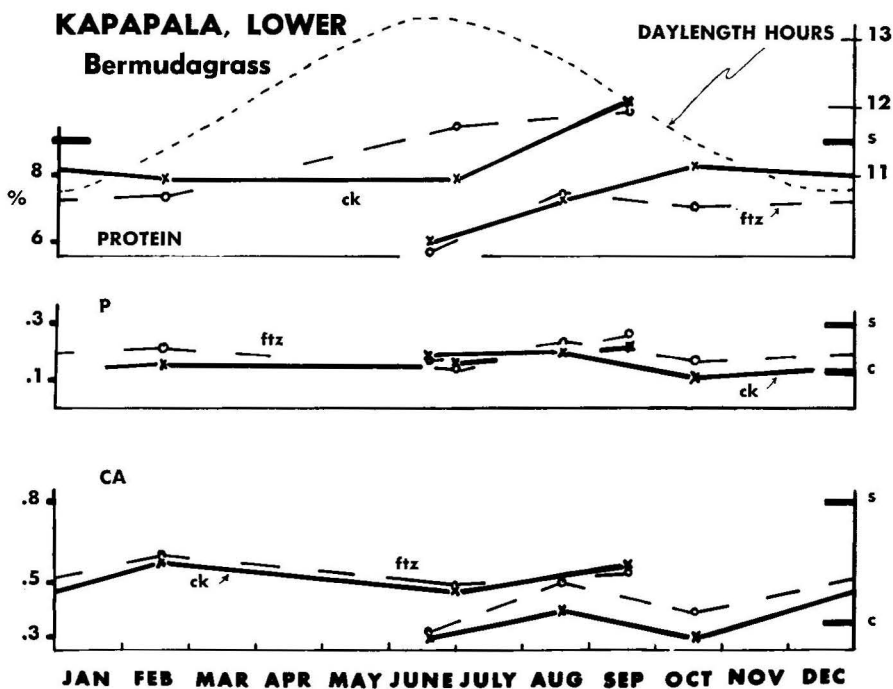


FIGURE 6. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

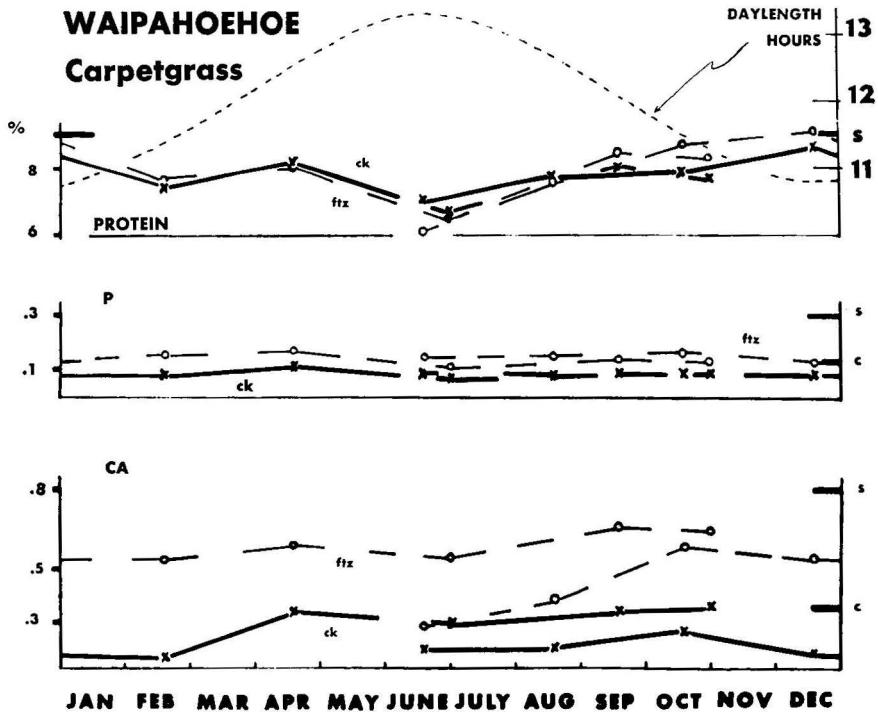


FIGURE 7. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

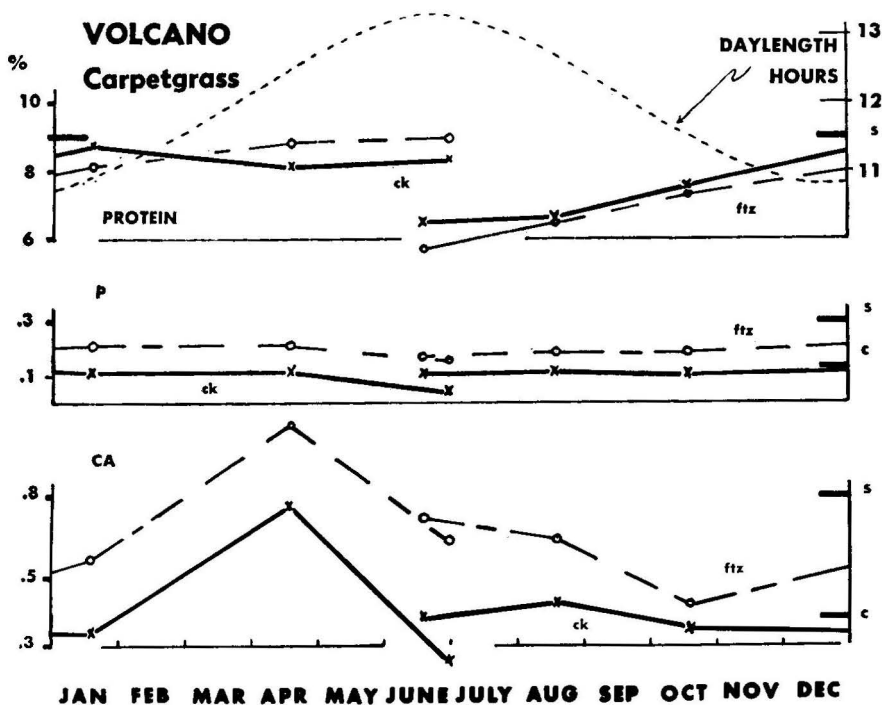


FIGURE 8. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

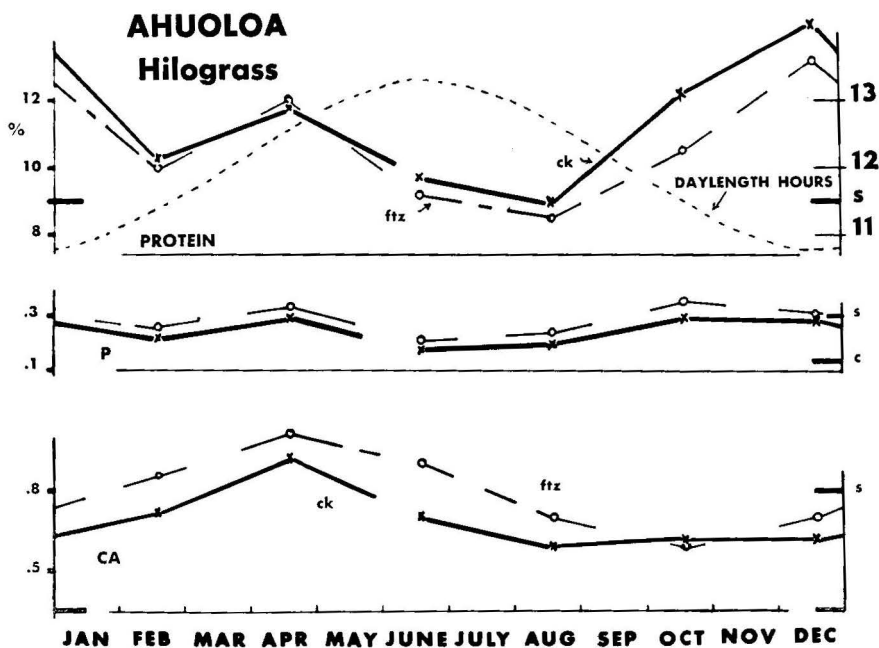


FIGURE 9. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

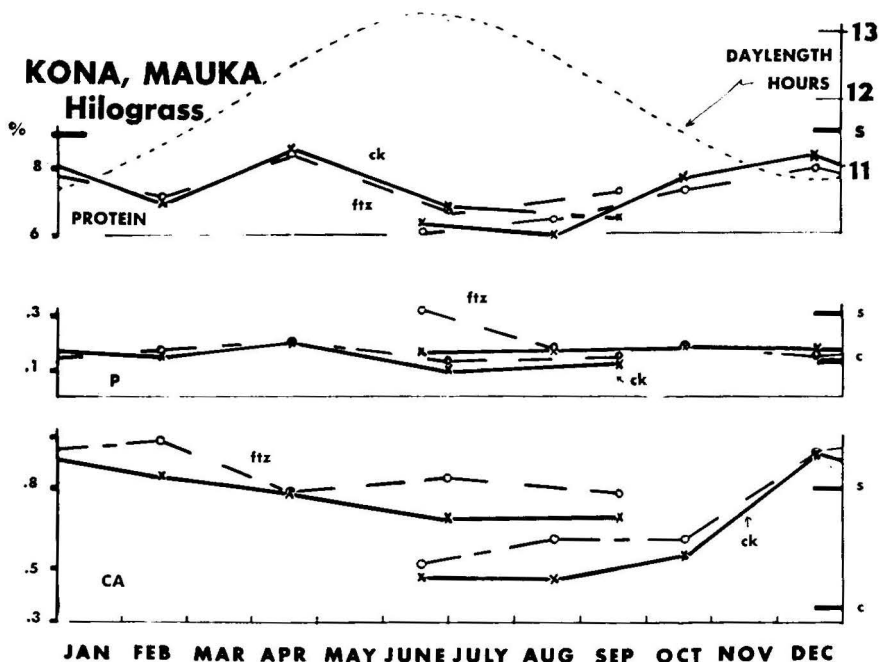


FIGURE 10. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.

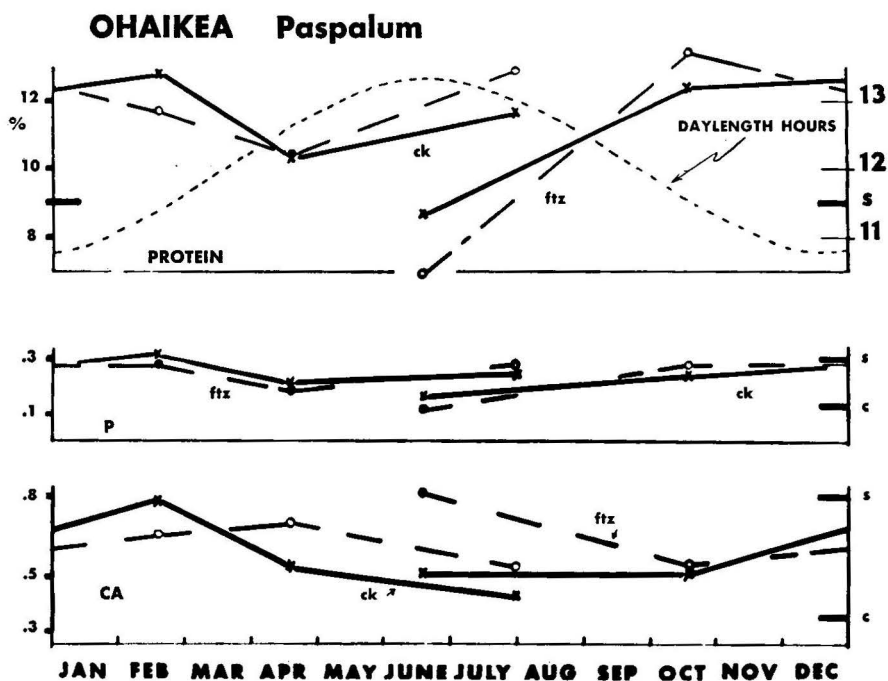
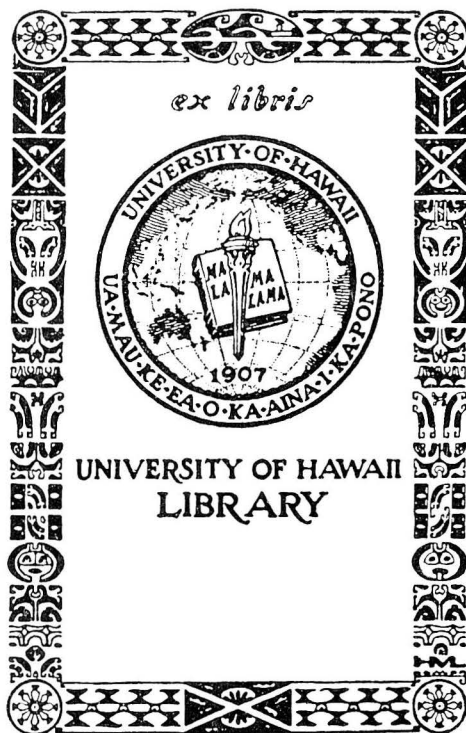


FIGURE 11. Chemical composition of Hawaii range grasses as affected by season, location, soil, and other factors (see table 1). The curves (top to bottom) show the content of protein, phosphorus (P), and calcium (Ca) in the oven-dry grass forage at different seasons. Curves marked "Ftz." represent forage from fertilized plots receiving 2000 pounds of liming material and 500 pounds of superphosphate, 20 percent P_2O_5 , per acre. Curves marked "Ck" or unmarked represent forage receiving no fertilization.



**UNIVERSITY OF HAWAII
COLLEGE OF AGRICULTURE
HAWAII AGRICULTURE EXPERIMENT STATION
HONOLULU, HAWAII**

LAURENCE H. SNYDER
President of the University

MORTON M. ROSENBERG
Dean of the College of Agriculture
and
Director of the Hawaii Agricultural
Experiment Station